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ON THE CONSERVANCY OF RIVERS, PREVENTION OF FLOODS, DRAINAGE, AND WATER SUPPLY.

BY

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PRESIDENT.

Dec 4

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Gentlemen:—

A very little consideration will show that the subjects of Conservancy of Rivers, Prevention of Floods, Drainage, and Water Supply, are so intimately connected, that any scheme of legislation for the one, without reference to the other, would be imperfect. The Public Health Act of 1875, and other Acts, have provided for drainage and water supply, and the "Rivers Conservancy and Floods Prevention Bill," when made law, will provide the want that is now so generally felt, with respect to the other two subjects.

By Royal Commissions and other means of investigation, an immense amount of most valuable information has been obtained on the subject-matters of my address. I would draw particular attention to the inquiries and discussions on National Water Supply, Sewage, and Health, which have taken place at the Society of Arts during the last few years,—H.R.H. the Prince of Wales, K.G., having suggested the discussion on National Water Supply.

In the course of my address, I shall frequently refer to some of the most important evidence that has been given and published.

My object is to endeavour to create a greater interest in these matters of such public importance, and on which the health of communities to a very large extent depends.

CONSERVANCY OF RIVERS.

The constitution of a Conservancy District and establishment of a Board, is provided for in the "Rivers Conservancy and Floods Prevention Bill"—as amended by the Select Committee—in the following manner:—

3.[1] "Any twenty or more owners, or any twenty, or more, owners and occupiers, of whom one half at least shall be owners, of land

[1] The figures refer to the clauses in the Bill.

of a rateable value in the aggregate of not less than two thousand pounds, and situate in any river basin or contiguous river basins; also,

"Any Sanitary or Conservancy authority having jurisdiction within any part of a river basin or contiguous river basins,

"May apply to the Local Government Board by petition praying that such basin or basins, or any part or parts thereof, may be constituted a Conservancy District; and that a Conservancy Board may be established therein, having power to execute all such works as may be required for the prevention of floods in such district, and for carrying into effect the purposes of this Act, and shall in such petition describe by reference to a map the district for which it is proposed that the Conservancy Board should be established."

4. "On the receipt of the petition the Local Government Board may, if they think a sufficient primâ facie case has been made out, and after requiring security to be given for any costs which may be incurred by the Local Government Board in relation to any local inquiry directed under this section, direct a local inquiry to be made by an inspector as to the expediency of constituting the proposed district, and as to the limits to be assigned to such district, and as to such further incidental matters as the Board may think fit; and in particular the inspector shall inquire what lands ought to be described as lowlands, midlands, and uplands for the purposes of this Act, and what works, if any, have been executed for the protection of any such lowlands or midlands from floods, and in what proportion such lowlands, midlands, and uplands ought respectively to contribute to the expenses of the Conservancy Board or some of them."

7. "In constituting a Conservancy District under this Act, the general principle of division of lands shall be to describe lands subject to ordinary floods and to damage therefrom as 'lowlands,' and lands occasionally subject to floods or to the entire or partial destruction by flood of drains or outfalls passing under or through them and to damage therefrom as 'midlands,' and the remaining lands included in the district as 'uplands.'" [1]

33. "Two or more Conservancy Boards may combine together for the purpose of executing, or of executing and maintaining, any works that may be for the benefit of their respective districts or any part thereof, on such terms as to payment or otherwise as may be agreed."

37. "The Council of a municipal city or borough having, according to the census for the time being in force, a population of not less than twenty-five thousand inhabitants, may, on their application, be constituted by provisional order made by the Local Government Board, after such local inquiry as required by this Act, a Conservancy Board for a district corresponding with the area of their municipal jurisdiction."

Provision is also made to invest on application any *existing* Conservancy authority with powers of the Act.

[1] These lands, respectively, are to be shown on a map, by a pink, blue, and yellow colour; and the Conservancy District denoted by being surrounded with a red line.

"The word 'Conservancy,'" says Mr. J. Clarke Hawkshaw, M.Inst.C.E., "when applied to rivers in this country, has generally hitherto been held to mean the keeping of them in a fit state for navigation. When our rivers were more used as highways, most of them had Conservancy Boards for navigation purposes. As long as such bodies prospered, our rivers were kept in far better order than they now are, not only for navigation, but for other purposes. Some of these Boards have disappeared, some remain, and still retain their powers, but many are unable, for want of funds, properly to do their duties.

"For this reason, and from the growth and spread of population along the river banks, new forms of conservancy have become necessary. Pollution by town refuse led to the passing of the Rivers Pollution Prevention Act, in 1876. The greater frequency of floods during late years has made it plain that conservancy for their prevention is necessary, and has given rise to the Rivers Conservancy Bill.

"Land Drainage Boards we have in plenty; each one does something, often little enough, to ward off floods, in its own district. But their sphere is too limited, they rarely look beyond their own narrow banks, and they will not work together. What we want to find out is how to control and direct their work, so that, when possible, it may be made to benefit all, and also to aid it by works which no one of them could undertake. . . . . .

"The whole of each natural drainage district should be under one Conservancy Board. . . . . .

"Many of our ports are liable to be inundated by high tides, land-water floods, and combinations of the two. If the flood waters are passed to the sea more rapidly by improvements, this liability may be increased. It is therefore most desirable that no part of each natural drainage area should be left out of the union for conservancy purposes, least of all the lower parts adjoining the sea. If all are included, the interests of all can be watched and considered, and the best results may be obtained at the least cost. . . . . No doubt the lowlands will benefit most, as now they suffer most, and they should bear the largest burden of the cost."[1]

The late Prof. D. T. Ansted, M.A., F.R.S., in a paper on "River

[1] Society of Arts Annual Conference on National Water Supply, etc., 1879, pp. 101-105.

Conservancy," says: "The banks of an open river must at least be retained without deterioration; in most cases they will need improvement. In canalized rivers the whole system of lockage, as well as the banks, must be kept in good order. In every case, the bottom must be dredged, if the scour is not sufficient to remove the mud that would otherwise accumulate."

When "the whole country is parcelled out into a moderate number of conservancy districts,"—he continues—"there will need, on the part of the public officials appointed, much special and technical knowledge, in addition to the general intelligence they may be presumed to possess, and this special knowledge must have a tolerably wide range.

"It is quite conceivable that, if the Conservators of a district should be persons chiefly interested in navigation, the sanitation might suffer, or that too absolute a devotion to the sanitation or the fisheries, might result in serious obstructions to navigation. So, also, the measures taken to prevent flooding at certain important points, might interfere with the ultimate delivery of the water from the uplands to the sea, especially in tidal streams; or too rapid a delivery of the waters of a river into a wide extent of flat lands near its mouth, might swamp and injure lands brought and kept under cultivation at great cost. . . . .

"The Conservators of each river basin, or group of Catchments, united under one Board, will have special duties, according to the physical condition of the district taken in hand. In each case, some one or more interests will be paramount, and to these the others must, to some extent, give way, but they must not be neglected. . . . .

"It may, and does happen, that the rainfall naturally falling on the catchment area of a river system may, in part, or even entirely, be better employed, so far as the whole nation is concerned, in providing a water supply for one or more large towns, than for the dwellers on the banks or the riparian owners. If it is so, the private right must give way to the public need, although in such case full compensation should be given. If only a part of the water is taken, and the water is chiefly employed as motive power, artificial reservoirs may be constructed, the storm waters otherwise running to waste may be impounded, and water compensation given by sending down the stream daily a fair average of the water. In other cases, money compensation may be given. . . . .

"There are instances in which the channel of a river or tributary has been used for many years as a drain or common sewer, to carry away the waste of manufacturers, and there are other cases, in which the water of streams has been fouled by washing or cleansing operations necessary for carrying on important works. When the waters thus injured are feeders of streams which afterwards pass towns and other inhabited places, it may be necessary to prohibit such uses of the water; but great judgment is needed in so doing, for it may be possible to check and divert important sources of national wealth, by interfering with, and rendering unprofitable, staple manufactures in districts in which they have been long carried on. . . . .

"The duties of Conservators in regard to sanitation are very serious. Theoretically, and according to the belief of some authorities, every objectionable material allowed to enter any part of a stream, renders all the waters below suspicious. Practically, we know that no river in existence could be other than a mass of poisonous corruption if this were true, and that, on the contrary, almost all streams, except where the quantity of water is small and the pollution excessive, pass down after a short flow in a clear and apparently pure stream.

"There can, however, be no doubt that when manufactures are carried on on a large scale, and where high cultivation and heavy manuring are carried on in lands already deep-drained, a large quantity of polluted matter may pass into the stream. It cannot be denied that this is a source of danger. . . . .

"It should be the duty of River Conservators to decide what is safe and sufficient purification of effluent sewage waters coming from towns, and take care that no injury to health shall befall any river under their superintendence by neglect of proper precautions. . . . .

"The duties of the Conservators should extend over the whole of the river basins, to enable them to watch over and influence the outfall by controlling the rivers from their sources. . . . .

"The conservancy of rivers very directly affects the question of water supply to towns. That rivers must always be, as they have always been, the most valuable sources of supply for general purposes, is inevitable, and that in many cases due care has not been taken to preserve them from pollution is equally certain. . . . .

"Under the care of properly selected conservators, empowered to act,

and required to enforce the law against all who infringe it, there is no reason why every river in the kingdom should not be utilized in a reasonable way for power for manufacturers, and for the use of towns, and after all this be sent down to the sea in such a state as to do no harm to the human inhabitants on the banks, or to any fishery that the density of the human population will allow to exist near its outfall." [1]

Mr. J. Bailey Denton, M.Inst.C.E., states, "that no jurisdiction of rivers can fully develope their capabilities that does not extend from their source to the sea, and that inasmuch as many springs which feed rivers rise at a great distance from their trunks, and flow by minor courses through private properties, it follows that no conservancy can be perfect which does not extend beyond the main rivers and minor streams to the extreme watershed that is tributary to them. . . . .

"To render river conservancies competent to exercise that control over river systems, which would preserve riparian and private rights, while securing to the public the enjoyment of the chief element of health—pure water—the first step to be taken should be the collection of all existing information bearing upon the surface and subterranean waters within each river basin, prepared on such a form as to be immediately available and capable of enlargement as fresh information may be obtained. At present there is no reliable record of such data within the reach of either local authorities or engineers, although a mass of information exists in a scattered and very costly form, in the Ordnance and Geological Survey Departments, which might afford data whereby neglected springs and subterranean waters might be turned to account." [2]

It will be observed,—says Mr. J. Bailey Denton—in the present Conservancy Bill, "no direct reference is made to water supply, although such is the reciprocal bearing of that object upon river conservancy, that it is hardly possible to deal with one in a comprehensive way, independently of the other, without some prejudicial effect." [3]

Mr. G. J. Symons, F.R.S., and numerous other authorities consider that "the right division for all hydraulic questions is the river-basin,

[1] Society of Arts Annual Conference, 1879, pp. 94-97.
[2] Society of Arts Congress, 1878, pp. 42-44.
[3] Society of Arts Annual Conference, 1879, p. 110.

and that as regards fishing, water power, water supply, drainage, and sewerage, it would be a grand thing to have one supreme authority for each river-basin."[1]

In an interesting summary of the proceedings of the Society of Arts Conference on National Water Supply, Sewage and Health, held in May, 1879, the Chairman, the Right Hon. James Stansfeld, M.P. (ex-President of the Local Government Board), said, he advocated the formation of County Boards; and that, "if it were necessary to combine one or more counties for the purpose of forming a watershed area, you had only to make it a combined authority. . . . They should start with the administrative unit, the simplest area, the urban or rural sanitary district. . . . But when you wanted a larger area for some common purposes, the simple rule in his own mind was to have an aggregate of those smaller areas,—never to divide them."[2] "His view would be," says Mr. Stansfeld, "that County Boards, or combinations of them, should, in preference to newly created authorities, be charged with the conservancy of rivers and so forth. All he asked them [the Conference] to do was to assert the importance and advantage of respecting the system of local government, which they hoped to complete by the creation of the County Board, and to create a new and larger watershed authority, with some kind of regard to that system. . . . . The question of the conservancy of rivers had been inquired into, and the recognized opinion was that the only true remedy for the inconveniences and evils now existing lay in the constitution of watershed authorities. . . . . What he desired the Conference to lay down was, that whilst fixing upon the area purely with a view to the exigencies of the case, they had better construct the governing body through the County Boards, so as not to introduce confusion."[3]

A resolution embodying the above views was carried unanimously by the Conference held in June, 1880.

I will now treat on the second subject in the heading of my address, viz.:—

PREVENTION OF FLOODS.

The Conservancy Bill, amongst other matters, thus provides for the Prevention of Floods:—

[1] Society of Arts Congress, 1878, p. 71.
[2] Society of Arts Annual Conference, 1879, p. 186.
[3] Society of Arts Annual Conference, 1880, pp. 19—20.

10.[1] "In order to carry into effect the purposes of this Act," viz. the conservancy of rivers and the protection of land from injury by floods,

"A Conservancy Board may within their district, (i.) cleanse, repair or otherwise place and maintain in a due state of efficiency any water-course or outfall for water, or any wall, bank, dam, or other defence against water, or do any other act for the purpose of *maintaining* in a due state of efficiency any work required to be so maintained for any of the purposes of this Act, and

(ii.) Deepen, widen, straighten, embank, extend, alter or otherwise improve any watercourse or outfall for water, or remove any mill-dam or other dam, weir or other obstruction to any watercourse or outfall for water, or raise, widen, or otherwise alter any wall, bank, mill-dam or other dam or other defence against water, or do any other act for the purpose of *improving* any work required to be improved for any of the purposes of this Act, and

(iii.) Make any new watercourse or new outfall for water, or erect any new bank, dam, or defence against water, or fill up or reopen any disused watercourse, or erect any machinery, or *construct* any other new work required for carrying into effect the purposes of this Act;

Provided that—

(1.) Compensation shall be made for all loss or injury sustained by any person by reason of the exercise by the Conservancy Board of any of the above powers, and the amount of such compensation shall in case of dispute be settled by arbitration in manner provided by this Act; and

(2.) No work shall be deemed a new work that is in substitution for an old one, where such old work is so much out of repair or so inefficient as to make it expedient to construct a new work in place thereof."

12.[1] "Every Conservancy Board shall from time to time ascertain whether the purposes for which the board was constituted are being carried into effect through their district, and in particular whether there are any obstructions to the flow of water therein, and whether the banks, dams, and other defences against floods are in a proper state of repair."

15.[1] "A Conservancy Board may from time to time make, alter and repeal bye-laws—

For prohibiting persons from throwing, etc., into any watercourse within their district any weeds, stones, soil or other solid matter calculated to cause an obstruction therein; and

For prohibiting persons from injuring any embankment or other work for the prevention of floods within their district; and

For regulating the opening and closing of flood gates, hatches, and sluices within their district in time of flood, or apprehended flood."

[1] Refers to number of Clause in the Bill.

There are special provisions made for fen lands, and also for not interfering injuriously, etc., with works of other authorities.

Mr. James Dillon, M.Inst.C.E., in a paper "On the effects of Under and Arterial Drainage on River Floods," states that:—

"The pollution of rivers, the silting up of their beds, and the damage caused by river floods, renders legislation on the subject necessary, and this applies not alone to England, but to the United Kingdom. True it is that great progress has been made with the removal of river-floods in Ireland, but further legislation is required. . . . . .

"Having charge of several river works in Ireland," he says, "I would wish first to state that, confining the floods in the upper reaches of a river valley within the river banks, instead of allowing the floods to spread over the banks, has not had the effect of increasing the floods to such an extent as to cause an increase in the damage done by the same floods in the lower reaches of the same valley below the termination of the upper works; and even admitting for the moment that theoretically, drainage works may have increased river floods, still it has been found impracticable to measure or value the damage, if any, caused thereby. . . . . . .

"Mr. R. Rawlinson, when giving his evidence in 1877, before the Lords Committee on Conservancy Boards, was asked, had the extension of drainage works very much increased the suddenness and violence of floods? answered, 'I do not believe that either drainage or cultivation affects floods in any appreciable degree.' . . . .

"It is, I think unfortunate," says Mr. Dillon, "that so many men of eminence still hold to the opinion that the destructive effects of modern floods are, to any appreciable extent, due to the extension of under-drainage. . . . . .

"Although under-drainage may slightly increase the volume of floods in winter from the uplands, still, by providing a suitable channel of sufficient capacity through a somewhat flat river valley, it has the effect of equalizing the flood discharges through the same, by drawing off at the commencement of the floods from the inner portion of the river basin (before the floods from the more distant portion of the same basin reaches them), some of that flood-water which before the execution of the works would have covered the river valley, and which, if left there, would have prolonged the duration of the floods,

when passing from the surface of the valley to the lower reaches of the same valley. At the same time under-drainage does certainly increase the summer flow, by gradually drawing off the water, which would otherwise escape by evaporation in summer, when most required for use." [1]

"The utility of reservoirs in diminishing damage from floods was taken into consideration in France after the inundations of 1856. Investigations were made in the valleys of the Seine, the Rhone, the Loire, the Garonne, and other important rivers, and resulted in the decision not to carry out the numerous reservoirs which had been proposed, owing to the uncertainty and doubtful efficacy of their action on floods.

"Similar investigations were made on these rivers after the inundations of 1875." [2]

"The French Forest Department in the Hautes and Basses Alps are carrying out extensive planting operations to replace the forests formerly destroyed. The replanting of these mountain sides has been going on for some time; already beneficial effect is felt in the diminution of the violence of the torrents. It is seen here, as in many other instances, that any rash interference with the economy of nature is attended with disastrous results." [3]

Mr. Danvers (of the India Office) says, "The destruction of trees on hill-sides, filled the rivers beyond what they were able to carry, and so caused floods along their banks." [4]

Prevention of Flooding—Prof. Ansted has stated—"requires close attention to the banks of the stream throughout, the construction of works, perhaps in the upper part of the stream, perhaps near the point where flooding usually takes place, and the maintenance of such works as exist. Where flooding is occasionally inevitable, owing to the physical conditions of the whole catchment area, provision requires to be made to *direct* [5] the flood, so that it will do as little damage as possible to towns and other inhabited places on the river course.

"In the case of certain rivers which flow over wide tracts of low-

[1] Society of Arts Annual Conference, 1879, pp. 97-101.
[2] Proceedings of the Institution of Civil Engineers, vol. lxvi. p. 408.
[3] Journal of the Statistical Society, vol. xli. part iii. p. 481.
[4] Journal of the Statistical Society, vol. xli. part iii. p 529.
[5] The italics are mine, J. H. B.

lying lands near the mouth, and reach the sea at a level little above low-water, the rivers are, in many cases, tortuous, and have no fall for a long distance. To assist the flow by shortening the river channel, and, where necessary, lift the water to a higher level to enable it to reach the sea, have involved the construction of great engineering works, which it is the duty of river conservators to superintend and keep in order. On the performance of these duties depends the safety of large populations, and the preservation of extensive tracts of land in a cultivable state. . . . .

"For purposes of navigation in a river, . . . the removal of accumulations of mud from the bottom is essential, such accumulations being in most cases inevitable. The removal must be effected by dredging, but the selection of a place for the deposit of what is thus removed may need careful consideration. It may be utilized in the formation of banks, or for raising banks already in existence, and may thus prevent flood; or it may be required to raise permanently the level of the valley in certain parts, or raise adjacent low-lands liable to flooding. On the other hand, it may be desirable to leave certain low-lands of little value unprotected, so as to permit flood waters to enter and remain for a time, and thus avoid serious inundation in other parts of the stream. To decide on such matters should be among the duties of the Board of Conservancy. . . . .

"To prevent a river, when in heavy flood, from so expanding at certain points of its course, as to avoid injury to towns or important manufacturing or other interests near its banks, has always been regarded as one of the chief objects of river conservancy. . . . . The injury from flooding is not only very serious as regards property, but it extends to human life, and, if possible, should be prevented. The works, however, that must be constructed to check this mischief require . . . . that the whole history of the river and each tributary should be carefully studied, and that the meteorology and geology of the whole Catchment should be as well known as the physical geography. . . . . In every division of the country, complications are sure to arise with reference to the times, places, and possible amount of flooding, that need constant attention to these physical conditions."[1]

Time will only permit me to make a passing reference to the recent floods that have occurred in the neighbourhood of Norwich. In my

[1] Society of Arts Annual Conference, 1879, pp. 94-97.

opinion—and I have an intimate acquaintance with the Valley Basin in which Norwich is situated—the disastrous flood that took place in November, 1878, *could have been prevented*, even with the existing appliances at the New Mills, had the necessary precautions been taken. The sluices constructed on purpose to provide for flood-water were not in working order, and were not utilized in the manner in which they ought to have been. Even when sluices are in working order, as they always should be, those who are in charge of them should not wait until the flood-waters are upon them before utilizing them. Frequently three or four days will elapse after heavy rain before the effect of the latter will be felt to any serious extent in the valleys. When there is an excessive rainfall, the sluices and flood-gates belonging to mills and other obstructions all down the river should be drawn up and opened (the amount necessarily depending upon circumstances), to allow water to pass down to the sea, and thus make room between the river banks for the unusual or excessive quantity of water that may reasonably be expected at such times.

The same provision should be made for snow directly the thaw sets in. Now, it is very seldom that such an immense amount of snow falls, and accumulates, like that of last January. At the time of the occurrence, I was residing, as I still am, in the upper part of the Wensum River Basin, and feeling confident another disastrous flood would take place at Norwich unless proper precautions were taken, I issued a timely warning in the *Eastern Daily Press*,[1] as soon as the thaw commenced. What took place? The sluices at the New Mills, being in working order, were entirely drawn up and left open all night for a few consecutive nights, and the water as it came down allowed to pass, and the city was thus saved, from what in all probability would have been another disastrous flood with its attendant miseries.

It is true, the miller suffered a little temporary inconvenience, in consequence of the large accumulation of water on the wrong side of his water-wheel, thereby preventing it working; and to endeavour to

[1] See "A Warning as to Floods at Norwich," *Eastern Daily Press*, January 29, 1881. In this communication, I suggested "that every possible precaution should be taken to prevent a similar, or worse, catastrophe to that which occurred in November, 1878, when so much misery was occasioned to the poor people residing in the flooded districts of the city of Norwich;" and I advocated, that "every facility should be provided for the unimpeded flow of the river Wensum through its sluices, and also through the narrow portions of its channel in the city."—J. H. B.

remedy this defect, the sluices were partly closed during the day-time; so that, a still larger mass of water could have safely passed through, had the sluices been entirely up during the day-time as well as the night. Of course, I knew the flooding of the marshes below Norwich was inevitable under the circumstances, especially as some of the marsh lands there are not protected by any banks whatever; but I also knew that comparatively little damage would be done. I inspected the flood on three different occasions, and heard some people state, that they considered there was a larger quantity of water then, than when the disastrous flood took place in 1878. I do not know whether any one has estimated the amount. I travelled to Great Yarmouth when the flood was at its maximum, in order to see the extent of it, and to see if any effect was produced at the outlet of the river. There was none whatever, the river was flowing as quietly and peaceably as possible, was not swollen, and there were no indications whatever down there, that anything unusual had happened up at Norwich. I travelled down again exactly a week after, and was astonished to find that the flood-waters had almost everywhere subsided, and the grass exposed.

As to the desirability of the removal of the New Mills, that is a subject I cannot now possibly enter into, as it involves many considerations of great importance. But I can say this, that so far as the *safety* of the low-lying portion of the city is concerned, it is not necessary.

The area of the water-way through the Mills might advantageously be increased, at a very little cost, by the erection of a large flood-gate, to be used in times of apprehended floods as a further security, and a few other simple improvements made.

I have referred thus much to the cause and effect of these local floods, because I think many people do not really know the facts. It is important, for, from want of this knowledge, engineering works on an unnecessarily large scale might be carried out, and the people heavily taxed for them, when in reality they are not required. As an Engineer and Geologist, as was also William Smith—the "Father of English Geology"—I would advocate the study of Nature as our guide, and the construction of works of simplicity, for the prevention of floods and other matters,—after the manner of William Smith when he shut out the sea from inundating Norfolk, by assisting Nature in

a work she herself was constructing against her own ravages, namely, an embankment of sand.[1]

I will now pass on to the following subject, viz. :—

DRAINAGE.

The Public Health Act of 1875 to a certain extent provides for "Drainage"; but, in the opinion of the Conference, held at the Society of Arts in June, 1880, "the Public Health Act of 1875, and the Pollution of Rivers Act of 1876, with other Acts dealing with public health, require revision and amendment in many important particulars."[2] In Mr. Stansfeld's opinion "sanitary statutes required some further elasticity. He was responsible [he says] for the original conception of special drainage districts when he passed the Local Government Act, but that method had its disadvantages, because as soon as you constructed a special drainage area it became a rating area for all purposes, and the multiplication of small rating areas was an objection."[3] Mr. A. H. Brown, M.P., said, "If you make the incidence of rating fair—which it is not at present—opposition to sanitary works will decrease, and therefore the public health will be improved."[4]

Mr. W. H. Wheeler, M.Inst.C.E., in a paper published by the Society of Arts, states:—"The disastrous floods of the last few years have raised a cry for improved drainage, which, if not carefully watched, will lead to the drying up of our springs and wells, and cutting off the natural sources of supply. The maintenance of the underground water level has been too much lost sight of in this cry for thorough drainage. So far as the tidal influence extends, this will always be provided for. The inflowing volume of tidal water running up a river twice every twenty-four hours has a most powerful effect in checking the flow of the underground currents and consequent exhaustion of the storage reservoirs. The hydrostatic power of the high tide in fact drives the water in these subterranean channels back, so that there may be said to be a corresponding rise and fall of the underground streams coincident with that in the sea

[1] See Geological Survey Map, Sheet 67 N.
[2] See Soc. of Arts Annual Conference, 1880, p. 38, etc.
[3] Soc. of Arts Ann. Conf. 1879, p. 165.
[4] Soc. of Arts Ann. Conf. 1879, p. 73.

and tidal rivers. This influence extends for a considerable distance inland. . . . The wells sunk along the high land known as the Cliff, extending from Grantham to Lincoln, which are from 100 to 150 feet deep, are affected by the state of the River Trent, which is twelve miles away, the River Witham intervening. The water commences to rise in these wells a very short time after the flood waters have risen in the Trent.

"Beyond the influence of the tidal current, this underground water-level can only be maintained by holding up the water in the main streams and arterial drains. This can be accomplished either by fixed or moveable weirs, the streams thus becoming reservoirs, not only advantageous for preventing the over-draining the water from wells and springs, but as providing storage for the supply of houses and farmsteads, for affording motive power to machinery, and also for irrigating the land in the dry season. The immense impetus given to all mechanical work by the use of steam has caused the more simple and natural agents of wind and water to be neglected. By one or other of these, the whole operation of pumping water, grinding meal, cutting chaff, thrashing corn, and other similar work, could, in many cases, be performed at a trifling outlay. . . . Again, for irrigating and fertilizing purposes, water is a most valuable agent, and far too little appreciated in this country. . . . .

"In the fens, the larger drains, when they discharge into the tidal stream, are provided with sluices with self-acting doors available in floods, and also draw-doors, which are put down directly the floods are over, the height being so regulated as to maintain the water at a fixed level, generally about three feet below the surface. The drains are supplied by feeders from the upland streams, which replace the waste from absorption and evaporation during summer. The extent to which this takes places may be gathered from the fact that in dry years no water at all passes out of the River Witham during the summer months, the doors for holding up the waters being placed across the river, about eight miles above its point of discharge into the estuary. During the dry season of 1864, these doors were closed for several months, and it was not until the month of December that there was any flow of water down the river to the sea, although the Witham has a drainage area of more than eleven hundred square miles, and is fed by a large number of perennial streams. The

experience gained in the drainage and water arrangements of the Fen districts may be usefully applied to other parts of the country.

"Our rivers should be made of sufficient capacity to carry off floods without damage to the surrounding land, and yet have their normal channels so regulated that the diminished quantity of the succeeding period of dry weather shall not have to meander hopelessly through a channel far too large for its requirements. . . . It is not drainage or storage only that requires consideration, but both. They are not incompatible, but each may be provided efficiently by a proper regulation of the rivers and water-courses." [1]

Sir Willoughby Jones, in a paper read before the British Association in 1868, calls attention to the obstructions to drainage in Norfolk, by mills damming up the rivers, causing stagnation and consequently a deposit of sediment, which raises their beds. He refers to the invasion of the *Anacharis Alsinastrum* or American water-weed, which, he states, fills, in places, half or two-thirds of the water-way, and which requires moving water to obtain its full development. He alludes, also, to the effect trees have—whether in masses or scattered—in increasing the rainfall.

Mr. Homersham, M.Inst.C.E., has said that, "he knew enormous areas of land covered with clay, having a subsoil of chalk, where what were called 'dumb wells' had been sunk through the clay into the chalk, and the drainage of the land had been carried into these 'dumb wells,' and was all absorbed by the chalk beneath. That was still carried on to a large extent in some districts, and he had found three generations of men who had been engaged in this occupation. In that case no doubt the effect of drainage was not to increase floods, because none of the water would be delivered into the river; it went into the chalk at an elevation varying from 500 to 600 feet above the sea; it went down into and along the great body of the chalk through fissures until it was discharged into the ocean by subterranean drainage. In this case surface drainage, instead of having tended to make floods in the river, had rather tended to diminish them." [2]

"In constructing a house on the sand hills of Sussex, or the chalk hills of Kent or Surrey," Prof. Prestwich observes, "it is the almost invariable custom to dig a shaft more or less deep into which the

[1] Society of Arts Annual Conference, 1879, pp. 83, 84.
[2] Society of Arts Annual Conference, 1879, p. 167.

house sewage and surface water are directed, and from which they disperse rapidly and disappear in the mass of permeable strata, as in a filter. . . . . There is another and more serious evil to guard against in some underground waters," he states, "and this is the consequence to be feared from blind wells communicating with the springs. . . . . A cemetery near London stands on a bed of gravel; under the gravel is London Clay, and beneath the London Clay are the water-bearing Lower Tertiary Sands, which hold the springs supplying the greater number of Artesian wells in London. I am informed," he says, "in order to carry off the water from the gravel in which the graves are dug, a dry or blind well was sunk through the London Clay into the underlying sands, and that into this well the drainage of the cemetery is diverted." [1]

Mr. Cresswell advocates "the desirability of getting rid of a nuisance throughout the country, which was universally accepted and acknowledged, namely, the intermarriage of the domestic well with the domestic cesspool." [2]

Mr. Stansfeld says the Society of Arts Conference "had always been of opinion that privies and middens ought to be abolished within a reasonable time, and that the pail system was a vast improvement on those old methods of dealing with excreta." [3]

The Rivers Pollution Commissioners, in their Sixth Report, have thus summarized the facts and opinions on the subject of—or what is called—*Previous Sewage or Animal Contamination*:—

"It has been established by very numerous chemical analyses, . . . that animal matters dissolved in water, such as those contained in sewage, the contents of privies and cesspools, or farmyard manure, undergo oxidation in lakes, rivers, and streams very slowly, but in the pores of an open soil very rapidly. When this oxidation is complete, they are resolved into mineral compounds; their carbon is converted into carbonic acid, and their hydrogen into water,—products which can no longer be identified in the aërated waters of a river or spring; but their nitrogen is transformed partly into ammonia; chiefly, however, into nitrous and nitric acids, which, combining with the bases present in nearly all water that has been

[1] Society of Arts Congress, 1878, pp. 63-64.
[2] Society of Arts Annual Conference, 1879, p. 177.
[3] Society of Arts Annual Conference, 1879, p. 184.

in contact with the earth, form nitrates and nitrites, and frequently remain dissolved in the water for a long time: there constituting a record of the sewage or other analogous contamination, to which it has been subjected since its descent to the earth as rain. . . . . There are several agencies at work by which this testimony, as to the amount of animal matter previously in contact with the water, may be weakened or altogether destroyed. Thus we look in vain for the full evidence of previous animal pollution in the effluent water from fields irrigated with sewage; because the growing plants have removed a considerable proportion of ammonia, nitrates, and nitrites, from the liquid as it flows amongst their rootlets. In like manner, the aquatic vegetation of rivers, lakes, and reservoirs, slowly removes these compounds from the water, and to that extent destroys the evidence of anterior animal contamination. . . . .

"The importance of the history of water, as regards its anterior pollution with organic matters of animal origin, does not arise from the presence of the inorganic residues (nitrates, nitrites, and ammonia) of the original polluting matters, for these are in themselves innocuous, but from the risk lest some portion (not detectable by chemical or microscopical analysis) of the noxious constituents of the original animal matters should have escaped that decomposition, which has resolved the remainder into innocuous mineral compounds."[1]

"The increasing pollution of rivers and streams," says Professor Frankland, "renders the supply of wholesome water from them more and more difficult." He had come to the conclusion that sewage had been the cause of the contamination of a certain water, because he found by analysis what may be regarded as the *skeleton* of the sewage, namely nitrogen in the form of nitrates and nitrites, and also ammonia, which latter, he said, was a very insignificant part of the skeleton. This chemical result, however, is defective, he says, especially in the summer months when aquatic vegetables remove the skeleton of the sewage to a greater or less extent from the water, and because it gives the minimum amount of sewage only with which the water has been contaminated.[2]

The Royal Commissioners report that, "The really injurious organic suspended matters are probably not merely organic but

[1] Rivers Pollution Commission, 1868, pp. 13-17.
[2] Society of Arts Congress, 1878, Previous Inquiries, p. 63.

organized matters—entozoic ova, or zymotic germs capable of reproduction in the human body with the simultaneous development of disease. Investigations of this class belong rather to microscopical than to chemical analysis, but even microscopic research is not yet competent to reveal any facts of direct importance in connexion with such organized suspended matters. The microscope has never yet discovered, even in the most polluted drinking water, any germ or organism which is known to be deleterious to human health."[1] And also, "that chemical analysis cannot discover the noxious ingredient or ingredients in water polluted by *infected* sewage or animal excreta; and as it cannot thus distinguish between infected and non-infected sewage, the only perfectly safe course is to avoid altogether the use, for domestic purposes, of water which has been polluted with excrementitious matters."[2]

Dr. Taylor, in 1851, in giving evidence on Sewage Polluted Water, stated, "I believe it is the opinion of every chemist who has considered the subject, that sewage matter does not remain as sewage matter in well aërated water, but that all phosphorus, sulphur, and nitrogen are speedily destroyed by the oxygen in that water. Every 1000 gallons of water will contain 46 gallons of oxygen, and that oxygen destroys all such putrescent effluvia. . . . . Nature seems to have provided for the mixture of sewage matter with water. . . . . In the Thames and other water, the air is in a state of solution, the matter in a state of diffusion, and thus the air and this fœtid matter are in the very condition to combine together and form an innoxious compound; it requires time and motion, but still it does take place with very extraordinary rapidity."[3]

The opinion of the Rivers Pollution Commission, published in 1874, is thus expressed:—

"It has often been asserted, but without proof, that the organic matter contained in sewage and other polluting liquids is rapidly oxidized during the flow of the river into which such liquids are discharged; and that if sewage be mixed with twenty times its volume of river water, the organic matter which it contains will be oxidized and utterly destroyed whilst the river is flowing 'a dozen

[1] Rivers Pollution Commission, 1868, p. 4.
[2] Rivers Pollution Commission, 1868, p. 17.
[3] Society of Arts, Congress, 1878, Previous Inquiries, p. 62.

miles or so.' We have," state the Commissioners, "made numerous observations and experiments upon the alleged destruction of sewage," and "have proved that *there is no river in Great Britain long enough to completely oxidize or destroy the soluble animal organic matter present in polluted water.*" [1]

Mr. Ernest Hart (Chairman of Council of the National Health Society), has stated—in a valuable paper containing statistics, etc.,—that, "the connection between impure water and diseases, although amply proved, does not rest on so exact an experimental basis as could be desired, probably on account of the imperfections of our present mode of analysis of water." There is, however, overwhelming evidence of the spread of typhoid fever by water. "Epidemics by the score, nay by the hundred," he says, "might be cited in which the first cause has been the pollution of the water drunk by the persons affected."

In 146 epidemics of typhoid fever reported by Mr. Simon, great excremental pollution of air or water—generally of both—was found in every case. "Since then, several very remarkable outbreaks of the same kind have been investigated by the Local Government Board with the same result. These reports may be broadly divided into three sections, those showing the impurity to be imparted (1) at the source; (2) in transit from the source to the reservoirs; (3) when stored in tanks or cisterns." [2] As Mr. Baldwin Latham had pointed out —said Mr. Ernest Hart—"these [poisonous] germs fertilized and multiplied much more readily *in darkness.* Some attempts had been made to reduce almost to a matter of measurement the bulk of water, the amount of air, and the quantity of light necessary to destroy these germs; but it was perfectly well known that all flowing streams tended to purify themselves, that if you oxidize any of these ferments, which were organic ferments of low structure, you practically disintegrated them, and filtration through the earth into a river which then flowed *exposed to light and oxygen* were conditions which tended to destroy the poison. Still, you could not depend on them absolutely." [3]

Mr. Rawlinson, C.B., Chief Engineer of the Local Government Board, speaking on the treatment of Sewage at the Society of Arts,

[1] Rivers Pollution Commission, 1868, pp. 134 and 11.
[2] Soc. of Arts Annual Conference, 1879, pp. 119—122.
[3] Soc. of Arts Annual Conference, 1879, p. 177.

in 1879, said, "It must be self-evident, when the matter was calmly considered, that where there were a multiplicity of inventions for the purpose of dealing with sewage, the Local Government Board, if it took up any one of these schemes and advocated its application, would offend the promoters of all the others. . . . . As far as they were informed by chemists, precipitation of any kind did not give an effluent that could be called pure. Assuming it precipitated some of the salts of sewage, the effluent took away certain of the salts of the precipitants which were put in, and therefore, there was practically an impure water. . . . . It might be a question as to whether, although an effluent was not chemically pure, the patentees or towns who chose to treat the sewage in that way should not be permitted to do so; for, in the eyes of the law, they were, and must remain, responsible for any pollution that might occur below them. He thought it would be most monstrous if the Government made a hard and fast rule, and declared that in all cases land and broad irrigation alone should be used. . . . . They had arrived at this point, that with regard to the dealing with sewage, it was absolutely impossible for scores of towns to acquire the land necessary to purify it by broad irrigation." [1]

Sir Henry Cole, K.C.B., in a paper, stated, "The following conclusions respecting farming by sewage now seem to be admitted: 1. That the storm water must be kept out of the sewers; 2. That precipitation must take place before the sewage flows on the land; 3. That filtration of some kind after precipitation is most desirable; 4. That towns cannot make a profit out of water-carried sewage." [2]

Mr. Edward Monson, Assoc.Inst.C.E., in an interesting report upon the Metropolitan Sewers, says, "I find that the sewers of the metropolis are, in many cases, sewers of deposit, and not constructed on the self-cleansing principle. . . . . Sewers of deposit mean the decomposition of putrid matter, and the constant formation of sewage gas. Sewage gas being constantly formed, it constantly escapes through the ventilators in the streets, and through any untrapped openings." [3]

At a meeting, in June, 1880, of the Sanitary Section of the Society

[1] Society of Arts Annual Conference, 1879, p. 178.
[2] Society of Arts Annual Conference, 1879, p. 124.
[3] Society of Arts Annual Conference, 1880, pp. 58-59.

of Arts, Messrs. W. Eassie, Rogers Field, E. F. Griffith (civil engineers) and others, gave important evidenee on various points connected with house drainage. Mr. Griffith said, "If the principle of disconnection from the sewer were right, it ought to be universally adopted everywhere. Another most important point about house drainage [he said] was this, that through nearly all drains being drains of deposit, they discharged putrid sewage into the sewers, and that reached the outfall in the form of sludge and slime which, if the houses were properly drained, they would not have to deal with. . . . If the drains were properly eonstrueted, the sewage would never stop from the time it left the eloset until it got to the outfall." [1]

It is impossible, says Mr. Conder, C.E., to separate the question of Water Supply from that of Drainage, for this reason: "Every ton of water brought into a town or house has to be removed when its work is done. Thus water supply and drainage are as closely related as are concave and eonvex."

This brings us to our last subject, viz.:—

WATER SUPPLY.

Although there are several provisions relating to Water Supply in the Publie Health Act of 1875, and Water Act of 1878, it seems not unlikely that further legislation on the subject will soon be requisite.

"Whether water (observes Mr. John Simon in his Report to the General Board of Health) can seeurely be drunk from rivers polluted by urban drainage, interests more or less every part of the country; and whatever faets can terminate this doubt, bear upon every plan for the water supply of a population, and upon every plan for the drainage of a town. . . . .

"It is, indeed, indispensable for the healthiness of towns that house drainage should be universally adopted, and that its eurrents should rapidly diseharge themselves beyond the inhabited area. But the advantages thus to be gained will suffer a serious counterpoise, if they can be purchased only at the cost of making the sewage outfall into rivers, if the change must be from an unwholesome house to a polluted water-source, and if that which would have been poison to inhale is to return as poison to drink. . . . .

[1] Society of Arts Annual Conference, 1880, p. 67.

"As town-drainage extends, successive populations a-down the stream get worse and worse water to drink, till the evil at length attains large and dangerous dimensions."[1]

"The Rivers Pollution Commission[2] of 1868, during the six years of its existence, collected evidence on the *quality* of water obtainable in different parts of England. The total number of examples they examined was 1274, representing waters collected from widely different districts, including spring water, deep well water, shallow well water, surface water, and rain water. In their Sixth Report (1874) they give the results of their investigations. Their information is grouped according to geological formations. . . . . They urge that preference should always be given to spring and deep well waters for purely domestic purposes, over even upland surface water, not only on account of their much greater intrinsic chemical purity and palatability, but also because their physical qualities render them peculiarly valuable for domestic supply. 'They are almost invariably clear, colourless, transparent, and brilliant — qualities which add greatly to their acceptability as beverages, whilst their uniformity throughout the year renders them cool and refreshing in summer, and prevents them from freezing in winter. Such waters are of inestimable value to communities, and their conservation and utilization are worthy of the greatest efforts of those who have the public health under their charge.' . . . .

"The *quantity* of water available for use in different parts of the country has not been ascertained with any accuracy. The primary source, the rainfall, has been studied for years, and Mr. Symons, F.R.S., furnished the Rivers Pollution Commission with a Map, giving a generalization of the results obtained; the amount of rainfall over districts being indicated by gradations in colour. But it is well known that the whole of the rain that falls in a district is not available as a water supply, and the amount that is available varies in different districts. The angle of the slope on which it falls, the character of the vegetation, and the lithological nature and geological disposition of the strata, are the more important causes of this variation."[3]

With respect to the determination of the rainfall of the British

[1] Soc. of Arts Congress, 1878, P. Inq. p. 63.

[2] Sir William Thomas Denison, Edward Frankland, and John Chalmers Morton, were the Commissioners appointed.

[3] Society of Arts National Water Supply Congress, 1878, P.Inq. p. 59.

Isles, Mr. G. J. Symons, F.R.S.—who has a volunteer-staff of nearly two thousand observers—states, "We arrive at the final fact, that although no part of the British Isles has, on the average, less than 20 inches of rain per annum, yet the bulk of the supply falls upon elevated mountain tracts, where it ranges from 50 to more than 100 inches per annum."[1]

Analytical results—the Commissioners state—illustrate very fully the influence which the chief geological formations exert upon the water which comes into contact with them. The following are the chief British geological formations which yield, as a rule, soft water:

Igneous, Metamorphic, Cambrian, Silurian (non-calcareous), Devonian (non-calcareous), Millstone grit, Non-calcareous rocks of the Coal-measures, Lower Greensand, London Clay, Oxford Clay, Bagshot Beds, Non-calcareous Gravel.

On the other hand, the following geological formations almost invariably yield hard water:—

Calcareous Silurian, Calcareous Devonian, Mountain Limestone, Calcareous rocks of the Coal-measures, New Red Sandstone, Conglomerate Sandstone, Lias, Oolites, Upper Greensand, Chalk.

In rendering the water sparkling, colourless, palatable, and wholesome, the following water-bearing strata are the most efficient:—

Chalk, Oolite, Greensand, Hastings Sand, New Red and Conglomerate Sandstone.[2]

"The improvement of the quality of drinking water by filtration has scarcely received so much attention as it deserves. . . . . The purest of natural waters owe their brilliant condition, and comparative freedom from that most objectionable of impurities—organic matter—to the exhaustive natural filtration which they undergo, in their passage from the foul surface of the earth to springs and deep wells. There is a great difference between this perfect process and the filtration through a couple of feet of sand, which is practised by water companies drawing their supplies from polluted rivers; nevertheless, evidence is not wanting to show that even this slight treatment is attended with a marked beneficial result; the improvement being due chiefly to the removal of impurities in suspension, but partly also to the oxidation and removal of organic matters in solution."[3]

[1] Soc. of Arts Congress, 1878, p. 71.
[2] Rivers Pollution Commission (1868), p. 130.
[3] Rivers Pollution Commission (1868), p. 216.

The "analytical results (made by the Commission) prove conclusively that sand filtration, as carried out at waterworks, not only clarifies the water by removing suspended impurities, but also diminishes appreciably the proportion of organic matter in solution (organic carbon and organic nitrogen) to an extent dependent upon the thickness of the filtering medium and the rate at which the water passes through that medium. . . . . The slower the rate of filtration the greater will be the clarification, and also, *cæteris paribus*, the purification from organic matter; but the latter depends still more upon the frequency of the cleansing of the sand." Analysis proves also "that filtration through *fresh* animal charcoal removes not only a large proportion of the organic matter present in water, but also a not inconsiderable amount of mineral saline matters." Still more remarkable results are obtained by the continuous filtration of water through metallic iron, prepared by the reduction of hæmatite ore, at the lowest practicable temperature, by carbonaceous matter. "The iron thus obtained is in a finely divided and spongy condition and appears to be a very active agent not only in removing organic matter from water, but also in materially reducing its hardness, and otherwise altering its character when the water is filtered through the spongy material;"[1] the remarkable properties possessed by which were discovered by Prof. Gustav Bischof, of Glasgow.

"Chalk is an excellent filtering and cleansing material for water, and, whilst it absorbs a larger proportion of the rainfall than does any other stratum, the water is again yielded to deep wells, in a condition of freedom from organic matter not surpassed by the water from any other geological formation. . . . . The Chalk constitutes magnificent underground reservoirs, in which vast volumes of water are not only rendered and kept pure, but stored and preserved at a uniform temperature of about 10° C. (50° F.), so as to be cool and refreshing in summer, and far removed from the freezing point in winter. . . . . There is reason to believe that the more this stratum is drawn upon for its abundant and excellent water, the better will its qualities as a storage medium become. Every 1,000,000 gallons of water abstracted from the Chalk carries with it in solution on an average 1¼ ton of the chalk through which it has percolated, and thus makes room for an additional volume of about 110 gallons of water.

[1] Rivers Pollution Commission (1868), pp. 217—220.

The porosity or sponginess of the Chalk must therefore go on augmenting, and the yield from wells judiciously sunk ought, within certain limits, to increase with their age."[1]

Hard waters from springs and deep wells can be easily and cheaply rendered soft by Clark's process, and the interests of the householder and manufacturer thus made identical.

The Commissioners report, that "the best rain water that could be collected from the roofs of houses is far less pure as regards organic pollution than water derived from deep wells or deep-seated springs. This result is not surprising when we reflect that the atmosphere, in a densely peopled country like Great Britain, is the recipient of vast aggregate quantities of impurity, derived partly from the respiration of animals, partly from the combustion of enormous quantities of fuel, and partly from excremental dust, the fine particles of which, in dry windy weather, become suspended in the air to the extent, over the area of this country, of hundreds of tons, and remain there for weeks unless washed out by rain. The condensation of moisture in the form of clouds in such an atmosphere must of necessity include the imprisonment of these dispersed particles in the excessively minute globules of water which constitute cloud and fog. Thus rain is in reality water which has washed a more or less dirty atmosphere. (Dew and hoar frost are even still less pure than rain water.) . . . . In Great Britain, and more especially in England, we shall, therefore, look in vain to the atmosphere for a supply of water pure enough for dietetic purposes."[2]

In the great majority of cases that have come under my notice, says Prof. Frankland, the polluted water of shallow wells which I have analysed could be replaced by a wholesome supply at a moderate expense, in one of several ways suitable of course to the different districts. "In many localities there are springs within a moderate distance of a village or group of houses; this water issuing from the spring usually joins a brook very soon after it comes from the spring, this brook is almost immediately polluted by drainage discharged into it, and the inhabitants have frequently to drink from this brook. The spring water could easily be brought in a pipe of very small diameter to the group of houses or village, and supply them with

[1] Rivers Pollution Commission (1868), pp. 101–102.
[2] Rivers Pollution Commission (1868), pp. 30, 31.

perfectly wholesome water. That is one way. Another way would be the digging of a shallow well, where water is to be obtained by shallow wells; but the well should be at a distance of not less than 200 yards from the nearest house, or drain, or cesspool, or other source of sewage pollution, and a pump should be erected there. The inhabitants would, of course, have to go that distance for their water, but it would then be fairly wholesome. There is a third plan which is available in every rural district, and that is the storage of water from roofs which are either tiled or slated. The tank in which it is stored ought to be either above ground, in which case, however, the water would get very warm in summer, or it ought to be in a perfectly water-tight tank under ground." [1]

Prof. Prestwich, F.R.S., says, "It is a sound principle laid down by the Water Commission of 1869, that each river catchment-basin should supply, as far as possible, its own population. There are cases, however, where the population of one basin, being much under its amount of water supply, no inconvenience could arise in diverting a portion of the surplus supply from any source to places in adjoining basins, where the population is in excess. So long, however, as this does not happen, and the river waters are maintained in a state of sufficient purity, so long should the towns in each catchment-basin look to the rivers and springs in that basin for their sources of supply. . . . . Each basin must be the subject of special inquiry, with respect to various conditions, of which that of geological structure is one of the most essential, whether as regards the sources that should be chosen as well as those which should be avoided." [2]

Referring to the Contamination of Wells, Prof. Prestwich says, "The evil is an accumulative one, and every now and then, we are reminded of its existence by disastrous and fatal results. . . . . Fortunately, natural agencies are constantly operating to counteract the evil consequences of our neglect. The power of oxidation and absorption of the soil on underground waters, goes far to remedy the evil and restore our springs and rivers to their original purity. . . . .

In our larger towns, where cesspits are gradually being done away with, the wells may improve, ... and might be again rendered available for use." [3]

[1] Soc. of Arts Congress, 1878, P. Inq. p. 82.
[2] Society of Arts Congress, 1878, p. 66.
[3] Society of Arts Congress, 1878, p. 62.

Dr. John Evans, F.R.S., in a communication to the Society of Arts, has stated, that, "It must never be forgotten that the water supply of any given locality is most intimately connected with the geological features of the district, ... and it is evident, that for the supply of the population in districts of different geological character, different means must be adopted. . . . .

"It would appear that the principle should be maintained that each town should draw its supply within the watershed on which it is situated, and only under most exceptional circumstances, be allowed to go beyond it. . . . .

"The position of nearly all our small towns and villages has been determined by the existence, upon the spot, of a more or less abundant supply of water. In many instances this is derived from shallow wells, which, owing to the neglect of proper drainage and sanitary precautions, have become dangerously polluted. In such cases, where it is quality rather than quantity that is defective, it is, perhaps, drainage rather than water supply that ought to be studied." [1]

Mr. Edwin Chadwick, C.B., in an important paper respecting Metropolitan water supply, refers to the superiority of the constant over the intermittent system of distribution; and states, that about 30 years ago Mr. Mylne—Engineer of the New River Company—displayed to him "one of the results of the hydraulic jerks, given by the intermittent system in loosening the joints of the mains so as to suck in the coal gas that permeated the subsoil of the streets," and also that "he gave clear evidence on the importance and economy of uniting the house service with the mains, as parts of one system under one supervision." [2]

The Rev. James C. Clutterbuck, says: "The gradual depression of the water level in artesian wells under London has proved the impossibility of relying on that source for any *increased* supply; and may furnish a warning against trusting to artesian wells as a perennial source from such wells beyond the limits of the metropolis. . . . . The difficulties of the water question in nearly all large towns are too well known to require much to be said. Liverpool has failed to obtain a supply from deep wells; Manchester is to depend on Thirlmere. Other large towns, having exhausted their natural

[1] Society of Arts Congress, 1878, pp. 47-48.
[2] Society of Arts Congress, 1878, p. 30.

sources of supply, need to be warned that no sources are without a limit, and all quantities must be calculated on a minimum to be ascertained, not by an average rainfall, but by careful gauging of the streams which issue from the lakes, which are counted on as perennial reservoirs. The general supply to villages and smaller towns present many difficulties. It will be found that these, especially the most ancient, are placed on sites where water is, so to speak, at hand. Too often, through negligence or ignorance, these sources have been polluted and made unfit for use; this makes it difficult to find fresh and wholesome supplies. . . . A certain amount of geological knowledge is indispensable in this matter, and till such knowledge is duly brought to bear upon it, the question of water supply will not be duly understood or its difficulties solved." [1]

Mr. Hassard, M.Inst.C.E., stated Paris was supplied by aqueducts 160 miles long, Marseilles by one 90 miles in length, Vienna by one 36 miles in length, and Madrid by one of 40 miles.[2]

"The whole question," said Captain Douglas Galton, C.B., F.R.S., "seemed to him now to have come to a focus, and every one concurred in admitting that England should be divided into districts of some sort for the purpose of regulating the water supply. . . . It was quite clear that a very large portion of the information rested in the hands of the Geological Survey Department. . . . There were other departments which were strictly concerned with this matter, but now they were all scattered about. The Local Government Board seemed to be the legitimate focus for this information; . . . . he believed it was the department which must eventually have charge of all these matters. Parliament was at present concerned with a Bill for River Conservancy, and as Mr. Atchinson had remarked, River Conservancy and Water Supply must go hand in hand; . . . districts should be so arranged as to be self-contained in regard to the control of their water-supply and drainage, each district must consider for itself what are its own wants, and arrange for their supply." [3]

The first principle to be aimed at is cheapness, observes Mr. R. Rawlinson, C.B. The water must be made available for the population at the least possible cost, that is, at a cost within their reach.

[1] Society of Arts Annual Conference, 1879, pp. 84-85.
[2] Society of Arts Congress, 1878, p. 21.
[3] Society of Arts Annual Conference, 1879, p. 161.

Each of the three plans, storage, well-sinking, or taking water from streams, might be available for one district more cheaply than for another.[1]

Conclusion.

Before I conclude, gentlemen, I wish to explain I have had many difficulties to contend with in the construction of this address, not from the want of material, but from the superabundance of it. I have sifted a large amount of evidence bearing on this complex subject, which is one of *immense magnitude*; but, unfortunately, owing to the limited space and time at my disposal, I have necessarily been obliged to leave unused much of the valuable information I had collected. I think sufficient, however, has been produced to show the intimate connection of the four subjects of my address, viz. Conservancy of Rivers, Prevention of Floods, Drainage, and Water Supply. I have quoted men, living and dead, who *are authorities* (as dead men's works live, so to speak) on the subjects on which they have given evidence, and I have preferred to convey their own words, as water should be conveyed, from the fountain head, pure and uncontaminated in transit.

The "Rivers Conservancy and Floods Prevention Bill" is a *permissive* one; that being so, the success or non-success of it, if it becomes law, will necessarily depend on the harmonious working together of Conservancy Boards in every river basin, under the fostering care of the Local Government Board. *It should be the duty of all to work together for the general public good.* Much also will depend upon the intelligence of the officers who may be appointed to carry out the work. The requirements of every locality are best known to those who reside in it; therefore, much good may be done by local scientific societies, in the reading, discussing, and publication of papers bearing on the subject—not forgetting the linking together of "Scientia et Utilitas."

In conclusion, I would point out one subject I consider of paramount importance—which is not only a national but a world-wide evil—on which we want still further enlightenment, namely, how to dispose of sewage so that it should not pollute "the water we drink" nor contaminate "the air we breathe"?

[1] See Society of Arts Congress, 1878, P. Inq. p. 87.